

Thus, the Commission has proposed exclusive use assignments in the 150-174, 421-430 and 450-470 MHz bands.

The Commission has imposed co-channel separation or channel exclusivity even where the result has been that only two providers of the specific service at issue would result. For example, the Commission's recent proposal to redesignate the 28 GHz band for local multipoint distribution service would license two licensees in each area.<sup>47</sup> The Commission noted such rules would "reflect the maximum flexibility for licensees to construct communications systems in which the public is interested."<sup>48</sup> Moreover, it also noted that coordination and sharing criteria would be difficult to implement because "the multicell multipoint configurations in this proposal envision a wide area distribution of services which may foreclose the possibility of acceptable sharing conditions between satellite and terrestrial services."<sup>49</sup>

In its recent interactive video and data services proceeding,<sup>50</sup> the Commission stated it would "make frequency

assignments in this service on an exclusive basis."<sup>51</sup> Each market would have two licensees, yet the Commission expressly found that a competitive market would result.

. . . there are two frequency segments available in each service area or market. Consequently, there is the potential for two IVDS providers in each market, making possible direct competition. In addition, licensees providing IVDS service face competition from other technologies such as the public switched telephone network and interactive (two-way) cable television based systems.<sup>52</sup>

The Commission has thus recognized that, particularly when other types of technologies offer competitive alternatives, licensing of two service providers per market can promote a competitive environment.

Finally, the Commission can be assured that adoption of a co-channel separation environment such as Teletrac has proposed will provide for efficient and valuable use of this spectrum. In granting Teletrac's request for a waiver to provide service directly to individuals, the Chief of the Private Radio Branch stated

Pactel's location response system uses a wide band pulse technology that spreads transmitted energy across several megahertz of bandwidth, thereby reducing the amount of energy-per-hertz and interference to other

---

<sup>51</sup> Id. ¶ 54, 7 F.C.C. Rcd at 1637. "Exclusive" in that proceeding was defined to mean that "a licensee is the only party authorized to transmit in the assigned frequency segment in the service area the licensee is authorized to serve." There would be no real exclusivity here because of the shared use among ISM, Government, LMS, Part 15 and amateurs. Id.

<sup>52</sup> Id.

services authorized in the band and enhancing the efficient use of the spectrum. Manifestly, PacTel's system increases communications options by providing the public with a new, innovative service.<sup>53</sup>

Should Teletrac's proposal for co-channel separation of wideband systems be adopted, the Commission will have created an environment that will permit such efficient, innovative service to continue.

- (a) Until [five years after effective date of new rules], no new license applications will be accepted in the 904-912 and 918-926 MHz bands for wideband systems that are located within 180 km (112 miles) of any previously licensed co-channel wideband system as determined by the distance between coordination points. Existing licensees and potential applicants shall each specify a coordination point determined from Table 1 of 47 C.F.R. § 90.635. Outside urbanized areas, the coordination point shall be the center point of the LMS service area.
- (b) No potential applicant shall install a fixed receive point more than 90 km (56 miles) from its own coordination point.
- (c) No potential applicant shall specify a forward link transmitter site more than 80 km (50 miles) from its own coordination point.
- (d) Forward link transmitters shall be subject to the following limitations on distance from coordination point and antenna height, based on a transmitter ERP of 300 watts.

Distance of transmitter from coordination point	Antenna height above average terrain for maximum power forward link transmitters (300 w ERP)	
	(Meters)	(Feet)
(km)		
0-10	450	1,476
10-20	350	1,148
20-30	250	820
30-40	200	656
40-50	125	410
50-60	80	262
60-70	40	131
70-80	15	49

- (e) Potential applicants may specify locations and antenna heights that do not conform to these restrictions upon prior written agreement by all licensees where coordination points are within 110 miles of the coordination point of the proposed facility.
- (f) Any license issued after [five years after effective date of new rules] shall be secondary to, and shall not cause interference to, wideband systems first licensed prior to November of that date.

### **C. Other NPRM Proposals**

#### **1. Equipment Authorization**

Paragraph 28 of the NPRM requests comments on whether LMS equipment should be type accepted. Units approved for use in the LMS service should be subject to equipment authorization to document compliance to power, bandwidth, frequency stability and spurious emissions requirements. Equipment authorization should become mandatory and should begin one year after the effective date of the permanent rules. Equipment authorization should also apply to tag readers, used by several current identification system providers, as well as to the reflector tags themselves. Certain types of tags operate as low power transmitters, receiving, modulating, and retransmitting a signal.

We believe that notification is the appropriate form of equipment authorization. Notification offers the least burdens to the Commission and to equipment providers and licensees. Under a notification mechanism, LMS licensees will have a strong incentive to assure that user equipment is in compliance, so as to promote efficient spectrum usage. A notification mechanism

can also promote technical innovation by reducing the regulatory burdens on new technologies.

## 2. Emission Types

Paragraph 30 of the NPRM requests comment on allowable emission types. Emission types should not be limited, assuming a co-channel separation requirement is implemented for wideband LMS. Without co-channel separation, however, strict technical

#### 4. Emission Limits

The requirement to suppress emissions outside the authorized bandwidth should reflect the realities of the 902-928 MHz band.

We propose that the  $55 + 10 \log (P)$  dB suppression apply only to

## **6. Warning Information**

Teletrac generally concurs with the proposal to advise consumers regarding interference potentials. NPRM ¶ 24. However, we do object to the requirement that this warning language appear on brochures, because this could be interpreted to mean marketing brochures rather than brochures supplied with the LMS device. The Commission's marketing rules (Section 2.801, et seq.) are already sufficient and need not be changed. The proposed language could cause confusion in interpreting the marketing rules. Consequently, we believe the warning language should be required only for instruction manuals and operating manuals.

## **7. Forward Links**

The Commission has proposed (NPRM ¶ 19) to allow wideband pulse-ranging LMS operators to retain their current authorizations for forward links, but has also asked for comment as to whether forward links should be moved into the same 8 MHz band as the operations they support. Wideband pulse-ranging technology is currently designed to operate with a forward link as deployed. Others, who have not yet built or operated a commercial system may believe there are other design technologies. But they have not been proven. Accordingly, we support the Commission's proposal.

## **8. Possible Interference-Induced LMS System Failures**

The Commission has sought comment on measures that might be needed to protect against life-threatening failures of LMS systems due to interference from Part 15 and other lower-priority users. NPRM ¶ 24. Total system failures are not likely to occur due to interference from these users<sup>55</sup>, partly because of the design of Teletrac's network, partly because we have educated some of these users to avoid our frequencies, and partly because of our incentive to minimize our service interruptions. Rather, we are more likely to get degraded accuracy rather than total system failure.

The interference risk from non-directional antennas depends on the power of the interfering signal. But, a signal strong enough to cause interference is also strong enough to locate through direction-finding techniques, and non-directional emitters are more easily located than directional emitters. It is in Teletrac's interest to locate sources of interference as quickly as possible.

We have worked successfully, we believe, to educate the amateur radio community about frequency sharing obligations in the 902-928 MHz band. This has minimized the likelihood of future problems, we believe. As we roll out our systems in additional cities, we plan to continue this education process.

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<sup>55</sup> However, as the preceding pages make clear, there would be a much greater likelihood of system failure from narrowband or co-channel wideband interference.

One might conceive of a life-threatening incident affecting an LMS user at exactly the same time that a new, previously undetected source of interference were to occur. The probability of the interference totally disabling the LMS system is very small. The joint probability of both occurring at the same time is even smaller.

### III. CONCLUSION

For the reasons stated in these Comments and accompanying Appendices, the Commission should adopt final rules for LMS service that will promote expansion of the industry. Teletrac believes its recommendations are amply supported and will help to achieve that goal.

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**CERTIFICATE OF SERVICE**

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JUN 29 1993

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FEDERAL COMMUNICATIONS COMMISSION  
OFFICE OF THE SECRETARY

In the Matter of  
  
Amendment of Part 90  
of the Commission's Rules  
to Adopt Regulations  
for Automatic Vehicle  
Monitoring Systems

PR DOCKET NO. 93-61  
RM-8013

To: The Commission

COMMENTS OF  
  
NORTH AMERICAN TELETRAC  
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VOLUME II

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APPENDICES

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- APPENDIX 2      Pactel Teletrac, Theoretical and Field Performance of Radiolocation Systems, June 25, 1993
- APPENDIX 3      Professor Richard Schmalensee and Dr. William E. Taylor, The Economics of Co-Channel Separation for Wideband Pulse Ranging Location Monitoring Systems
- APPENDIX 4      Declaration of Paul Jansen, McKinsey & Company, Inc.
- APPENDIX 5      Summary of the Rulemaking Proceedings Leading to Adoption of the 1974 Interim AVM Rules, 47 C.F.R. § 90.239



**Engineering Analysis of  
Cochannel Pulse-Ranging LMS Systems**

**by  
Professor Raymond Pickholtz**

**June 28, 1993**

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# Engineering Analysis of Cochannel Pulse-Ranging LMS Systems

## I. Introduction

In 1974 the FCC set aside two eight-megahertz bands (904-912 MHz and 918-926 MHz) for the operation of wide band pulse-ranging automatic vehicle monitoring systems.<sup>1</sup> The FCC is now proposing to adopt permanent rules for the operation of those systems (now which are to be renamed location and monitoring services). A principal issue in the proceeding is whether multiple LMS systems can share a single LMS band in the same city. We have been asked by PacTel Teletrac to examine the engineering and economic issues involved in sharing among systems. Our goal has been to be objective, and we believe we have achieved that goal. However, our analysis led to a clear conclusion: Sharing among LMS systems is not reasonably feasible for a variety of

## II. The Problem of Interference

Examples of radio interference abound. Turning on a hair dryer can disrupt the picture on a nearby TV. Bringing an FM radio near a computer can cause the radio program to be drowned out by the hiss and whine of the unintentional radiation from the computer. Someone listening to a far-off AM station in a car at night will hear a sudden roar of static as he or she pulls the car into a service station and parks the car under a bank of florescent lights. CB radios sometimes cause interference to TV reception.

Related to the concept of interference is the concept of harmful interference — interference that has negative economic or social consequences. The FCC defines

harmful interference as interference that seriously degrades or repeatedly interrupts a radio communications service.<sup>2</sup> For example, the FCC's rules governing private microwave systems generally prohibit any interference that will raise the noise threshold of a receiver by 1.0 dB.<sup>3</sup>

Harmful interference can adversely impact any wideband pulse-ranging location and monitoring system in several different ways. For example:

- interference can significantly degrade the accuracy of location estimates provided by the system;<sup>4</sup>
- interference can create holes in the coverage area — regions where accuracy is profoundly degraded or the system does not function at all;
- interference may reduce capacity thereby increasing costs to consumers as fixed costs must be recovered from fewer customers or even reduce capacity below the point where the service is economically viable;
- interference can create uncertainty about the acceptable functioning of the service and thereby make users unwilling to trust the system; and
- perhaps most harmful of all, interference can become so severe that receivers are unable to reliably determine the presence of pulses and therefore cannot even begin to measure the time-of-arrival of such pulses.<sup>5</sup>

---

<sup>2</sup> See 47 CFR § 2.1 Harmful interference depends not merely on how much interfering energy is present in the receiver or on signal-to-noise ratios, although these are important, but also on the nature of the system receiving interference.

<sup>3</sup> See 47 CFR § 94.63(c) or § 94.93(d)(2)(ii).

<sup>4</sup> Changing the average error of location estimates from 100 feet to 200 feet would be harmful interference while changing the average error from 100 feet to 100.5 feet would not. Again, harmful interference is an economic concept.

<sup>5</sup> Technically speaking, interference at sufficiently high levels will prevent the receiving subsystem in a pulse-ranging system from acquiring symbol synchronization.

The definition of harmful interference just looks to the threshold — the level where interference begins to have appreciable economic effects. But, of course, interference can go far beyond this level. Interference can become fatal — destroying system operation — not just degrading system operations.

### **III. Theory of Operation of Pulse-Ranging LMS Systems**

The basic idea of a wideband pulse-ranging system<sup>6</sup> is simple. A vehicle transmits a pulse of radio-frequency energy. The time-of-arrival of that pulse is precisely measured at several receive sites. Comparing the pulse's time-of-arrival at these various receive sites allows the transmitter's location to be computed. For example, if the pulse arrives at two receive sites at exactly the same time, then the transmitter must lie somewhere on the line running down the middle between the two receive sites. As a general matter, the line-of-position determined by any pair of measurements is a hyperbola.

Figure 1 is an illustration of this time-of-arrival measurement mechanism. Time-of-arrival measurements require extreme accuracy if accurate vehicle location is to be achieved. If multipath effects<sup>7</sup> are ignored, the difference in the time-of-arrival of the pulse at each base station in Figure 1 is directly proportional to the difference in distance to the two base stations.

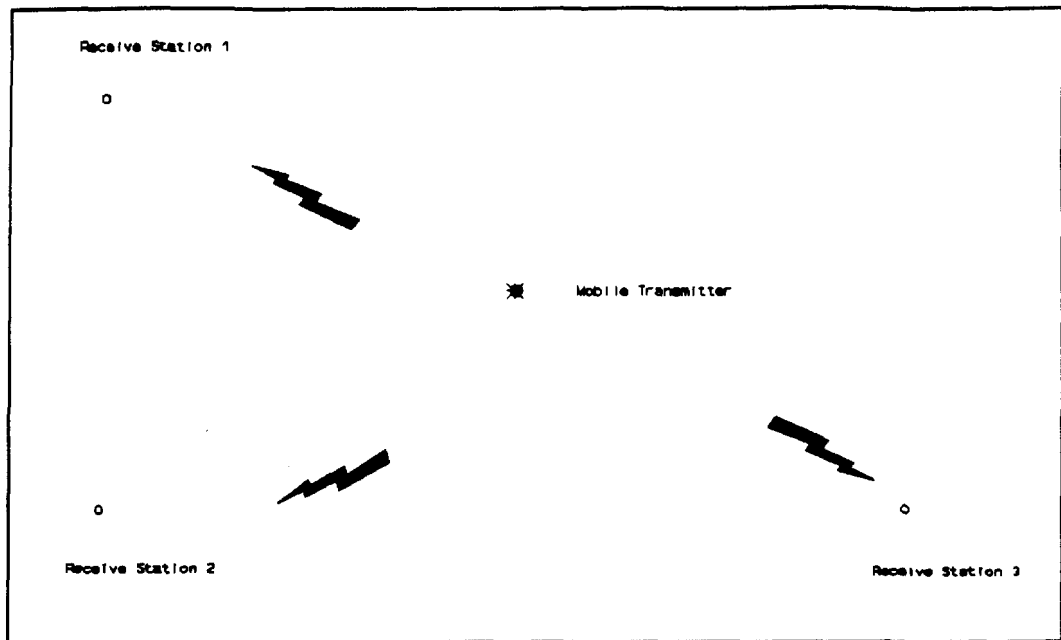
Each pair of the receive stations in the system determines a line-of-position — the set of locations where a transmitter would generate the time difference actually seen by that

---

<sup>6</sup> Our discussion here considers a class of systems including both those that use single, unmodulated pulses and those that use pulses modulated by a spread-spectrum waveform.

<sup>7</sup> Multipath refers to the combination of direct and reflected echoes that arrive at a receiver when the signal takes multiple paths from the transmitter. Multipath is responsible for ghosts in television. Multipath poses substantial challenges for pulse-ranging systems. Measuring the time-of-arrival of a weak pulse is complicated if an echo arrives at almost the same time.

pair of receivers. Figure 2 illustrates three such lines-of-position as would occur in the configuration shown in Figure 1. As Figure 2 shows, the lines-of-position all converge near a single region. The center of that region is a good estimate of the location of the vehicle.



**Figure 1**      Signalling from a vehicle served by an LMS system

Because pulse-ranging systems cannot know the exact time a pulse is transmitted, these systems must use time differences of pulse arrivals. This technique requires a minimum of four receive sites to guarantee an unambiguous location estimate. In practice, an operating pulse-ranging system would probably use more than four receive sites to improve the quality of the location estimates and to improve reliability.

Navigation systems like LORAN-C or GPS also use time difference of arrival (TDOA) computations. However, in pulse-ranging LMS systems the signals travel from the mobile to the fixed network — the reverse of LORAN and GPS — and the calculations are performed at the fixed end of the system, rather than in the mobile.

Any simple measure of interference effects, such as signal-to-noise ratio at a single point, is not appropriate for determining whether there is harmful interference. For example,